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INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY

International Journal of Psychophysiology 34 (1999) 163–169 www.elsevier.com/locate/physcho

Short communication

Increased emergence of alpha activity over the left but not the right temporal lobe within a dark acoustic chamber: differential response of the left but not the right hemisphere to transcerebral magnetic fields

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Received 24 April 1999; received in revised form 2 August 1999; accepted 2 August 1999

Abstract

The percentages of alpha activity per minute over the left and right temporal lobes were measured for the first and second successive 15-min intervals while subjects wore opaque goggles within an acoustic chamber. A weak (5 μT), burst-firing magnetic field was presented during this period for 1 s every 4 s primarily over the left or the right cerebral hemisphere. The results indicated that the left temporal lobe became less vigilant between the first and second 15 min while the right temporal lobe did not. When standardized scores for each subject's measures over time and across hemispheres were employed, increased alpha time over the left temporal lobe relative to the right temporal lobe was observed only when the transcerebral magnetic field was applied over the left hemisphere. Stimulation of the right hemisphere did not evoke this discrepancy. The detection of the effects of this specific complex magnetic field upon electroencephalographic activity may be more probable when the subjects are exposed to partial sensory deprivation. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Hemispheric asymmetry; Alpha activity; Temporal lobes; Transcerebral magnetic fields; Electroencephalography

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PII: S0167-8760(99)00069-0

The purpose of this study was to discern if weak (microTesla range) transcerebral stimulation by complex magnetic fields could affect the quantitative incidence of alpha activity even when counted manually. Transcerebral magnetic field stimulation differs from transcranial stimulation which employs strong (tesla range) magnetic fields that are applied as symmetrical pulses. Complex magnetic fields are defined as irregular, asymmetrical and usually frequency-, amplitude- or phase-modulated sequences of patterns generated by computer. They simulate the natural temporal patterns of electrical activity within aggregates of neurons. Subjects exposed to transcerebral stimulation by one specific relatively simple magnetic field pattern, modeled from 'burst-firing' neurons within the amygdala-hippocampal region of the human brain (Persinger et al., 1991; Richards et al., 1993), have displayed consistent changes that suggest involvement of the experiences of pleasantness (Persinger et al., 1994; Freeman and Persinger, 1996; Persinger et al., 1997), elevated nociceptive thresholds (Fleming et al., 1994) and reduced depression (refractory to antidepressant medication) following closed head injuries (Baker and Persinger, 1996).

Although this experimenter did not expect quantitative effects of repeating the same weak, complex magnetic fields upon the waking electroencephalographic (EEG) record of normal subjects, sensitivity of this activity to these fields during cerebral states involved with shifting dynamics between the two hemispheres (Gaillard and Laurian, 1984; Persinger, 1993; Casagrande et al., 1995) was considered more probable. However, even these quantitative effects of this complex magnetic field upon EEG activity would be so weak that their presence would only be evident if the major source of variance, individual differences, was minimized by employing each subject as his or her own control.

Thirty-two, right-handed, university students (16 men and 16 women), ranging from 19 to 27 years of age, served as volunteers in this study; they obtained a 2% bonus for their final grade in an introductory psychology course. Subjects were told they were recruited for a relaxation study that may or may not involve the presentation of weak magnetic fields (whose strengths were less than those generated by hairdryers) through the brain. After informed consent, each subject sat within a comfortable armchair that was housed within a commercial acoustic chamber. Silver electrodes were attached by EC2 electrode cream to T3 (left temporal lobe) and T4 (right temporal lobe); the reference electrodes were to the ipsilateral ear lobes. A modified motor cycle helmet was placed carefully over the person's head. The helmet contained four pairs of solenoids embedded in an epileptoid pattern on the left and right side within the approximate position of the temporoparietal region (Richards et al., 1993; Persinger et al., 1997). The person was then blindfolded by placing halves of a ping-pong ball filled with cotton over each eye. The subject was requested to relax, with the eyes closed, until the end of the experiment. However, to minimize any potential anxiety each subject wore a lapel microphone and was told that if the experience became uncomfortable they could contact the experimenter and the experiment would be terminated immediately.

During the 30-min period the electroencephalographic activity over the left and the right temporal lobe was recorded continuously by a P79 (three channel) Grass EEG; the third channel served as an indicator of the presence of the magnetic field. For 18 of the subjects the switches on the solenoids were set to primarily affect the left hemisphere while the other 18 subjects received the stimulation primarily over the right hemisphere. The subjects were given this treatment in an alternating order by an experienced technician who was not familiar with the purpose of the experiment. There were no more than two subjects tested per day and there were equal numbers of men and women per group. Direct measurements indicated that the activated solenoids produced a field whose strength was approximately 10 times stronger than the non-activated solenoids. The maximum field strength over the stimulated hemisphere ranged between 1 and 5 μT (10 and 50 mG) at the level of the scalp. Air measurements at the approximate distance of the deep layers of the cerebral cortices ranged between 200 nT and 1 μT.

The complex magnetic field was generated from a series of 230 numbers which defined the 'burst' pattern (Richards et al., 1993) that has been asso-

ciated with pleasantness and elevated nociception. The initial form of the burst pattern was extrapolated from profiles of amygdaloid neurons from epileptic patients. Each value for the series of numbers that generated the pattern ranged from 0 to 255 (−5 V to +5 V) where 127 = neutral polarity and values below or above 128 were negative and positive polarity, respectively. These values were transformed from the Zenith XT personal computer (port latency = 140 μs) by a custom-built digital-to-analogue converter to the appropriate voltage and then generated through a commutator that activated successively each pair of the opposing solenoids for 0.5 s. Consequently the pattern was rotating spatially over the temporoparietal lobes once every 2 s as suggested by the results of previous research (Persinger et al., 1974).

The pixel duration of each point (the value between 0 and 255) was 3 ms. The resulting burst pattern occurred for approximately 700 ms. The time between the presentation of the pattern was 4000 ms (4 s). There were 380 presentations of the pattern during the 30-min period. With these particular parameters and method of field application over either the left or the right hemisphere, sound artifacts (if present) from the intermittent activation of the solenoids were not apparent. (In pilot studies subjects exposed to either sham fields or to the magnetic fields did not display any significant group differences with respect to reporting 'odd sounds' or noises during the procedures). At the end of the experiment the equipment was removed and the subject was instructed to report any unusual experiences that might occur during the subsequent 24 h (no one reported any unusual experience although five of the subjects left telephone messages reporting 'very vivid dreams' the night after the exposure).

The entire EEG record for each subject was evaluated by a paid senior neuroscience student who was blind to the condition of the subject. Because of the paper speed, each strip of EEG paper contained 20 s. By examining each successive second, the evaluator determined the number of seconds that contained alpha activity over the left and right temporal lobe per 20-s page. Alpha activity was defined as any discernable patterns that were between 8 and 13 Hz, including the conspicuous alpha rhythm (Makarec and Persinger, 1990; Persinger and Richards, 1994).

To be counted, the alpha frequency was required to fill the entire second. The inter-rater reliability for this method (based upon 100 ratings) was $r = 0.87$ (the second rater's data were not included in the analysis). The numbers of alpha seconds were converted to the percentages of time that alpha activity were displayed over each temporal lobe during the first 15 min and the second 15 min of the study.

The data were analyzed as a function of a four-way analyses of variance (MANOVA) with two levels repeated (left and right temporal lobe for each subject; first 15 min, second 15 min for each subject) and two not repeated (gender; application of the burst-firing field over the left or the right hemisphere). Because any effect from the transcerebral magnetic field upon the duration of alpha activity over the temporal lobes would likely have been masked by individual differences, the z-score for each of the four measures for each subject (first vs. second 15 min and left vs. right temporal lobe), referenced to the mean and S.D. for the four values, was calculated. All analysis, including post-hoc testing, was completed with SPSS software on a Vax 4000 computer.

The results of the four-way analyses of variance employing the percentage of alpha activity per minute demonstrated no statistically significant differences ($P > 0.05$) between gender ($F_{1,28} = 1.31$) or the hemisphere over which the transcerebral magnetic field was applied ($F_{1,28} < 1.00$); the interaction between these two variables was also not significant statistically ($F_{1,28} < 1.00$). There were also no statistically significant differences in the alpha time over either temporal lobe as a function of the two blocks of time or interactions with gender or the hemisphere that received the transcerebral stimulation (all Fs < 3.00).

The only statistically significant interaction occurred between the percentages of alpha time over the left and right temporal lobes as a function of time ($F_{1,28} = 17.85$, $P < 0.001$; partial $\eta^2 = 39\%$). Post hoc analysis employing paired t-tests indicated that the primary source of this interac-

tion was the differential increase in the percentage of alpha activity over the left temporal lobe between the first and second 15 min (paired t-test $= 3.72$, $P = 0.001$) in the chamber relative to the right temporal lobes activity that did not change significantly ($t = 0.18$, $P > 0.05$) during this period. Fig. 1 shows this effect.

The second four way analyses of variance, employing the z-scores of the four measures of alpha time for each subject (in order to eliminate the contributions for individual variance) also showed the statistically significant interaction between the two successive blocks of time within the chamber and the left vs. right temporal lobe ($F_{1,28} = 22.15$, $P < 0.001$; $\eta^2 = 44\%$). In addition to the differences in the overall amount of alpha activity between the two temporal lobes ($F = 8.91$; $\eta^2 = 24\%$), which was confounded by the interaction between time and hemisphere, this analysis also demonstrated a statistically significant interaction ($F_{1,28} = 4.58$, $P < 0.05$; partial $\eta^2 = 17\%$) between the percentages of alpha activity over the left and right temporal lobe and the hemisphere over which the transcerebral fields were applied (Fig. 2). Post hoc analysis by paired t-tests indicated that the primary source of this interaction was due to the increase in the proportion of alpha activity over the left temporal lobe when the magnetic fields were applied over the left hemisphere and a decrease in alpha activity over this temporal lobe when the fields were applied over the right hemisphere ($t = 5.04$, $P < 0.001$) in context of no change in alpha activity, regardless of hemisphere of application, for the right temporal lobe ($t = 0.47$, $P > 0.05$).

The results of this study are consistent with the observations and conclusions of Casagrande et al. (1995) that the left hemisphere 'falls asleep' earlier than the right hemisphere. Although none of our subjects displayed any of the classical EEG signatures associated with early stages of sleep, such as alpha drop out and the emergence of 'sleep spindles' (which quickly generalize from the frontal regions into the temporal regions), the proportion of alpha activity over the left temporal lobe between the first and second 15-min period clearly increased while this activity over the right temporal lobe did not change. The effect size, which is the amount of variance in the percentage of alpha activity accommodated by this interaction, was approximately 40%. This size would be comparable to that derived from the results of the reaction time study by Casagrande et al. (1995).

The absence of change in alpha activity over

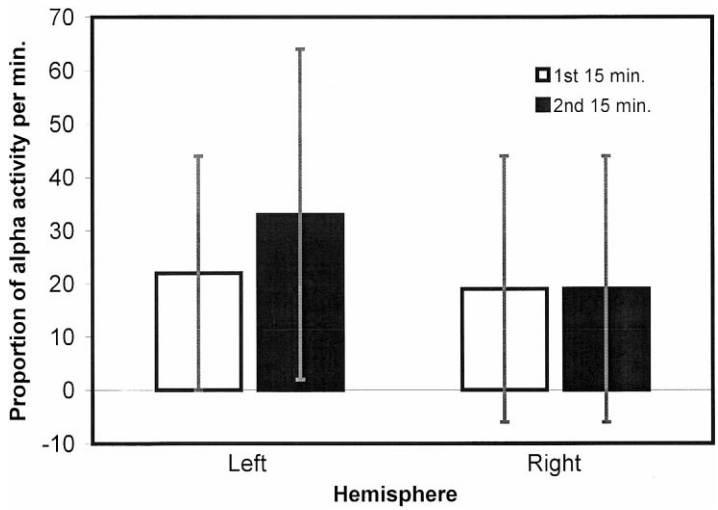

Fig. 1. Proportion of time alpha activity occurred over the left and right temporal lobes during the first 15 min and second 15 min of exposure to partial sensory deprivation. Vertical bars indicate S.D.

the temporal lobe of the right hemisphere would be congruent with the observations that the normal subjects still remained relatively vigilant to auditory input even though 'consciousness' in the traditional sense of self-awareness and related left temporal lobe processes had begun to disengage. A relative increase in alpha activity over the left temporal lobe, which we have found to be associated with increased references to imagery, would also be consistent with the reports of relaxation and pleasantness that accompany these episodes (Persinger et al., 1991).

The observation that a weak (< 5 μT, < 50 mG) burst-firing magnetic field presented every 4 s differentially affected the relative amount of alpha activity over the left temporal lobe but not the right temporal lobe suggests that the effects of these fields can be discerned if each person is employed as his or her own reference. Because there was more alpha activity over the left temporal lobe when the transcerebral stimulation was primarily over the left hemisphere but relatively less alpha activity over the left temporal lobe when the stimulation was over the right hemisphere, the likelihood of artifacts from electrical induction by the magnetic fields is minimal. Considering the 'averaged frequency' of the experimental pattern would be approximately 30 Hz, induction artifacts (which we have produced purposely to discern how contamination of a record would appear) should have masked the 8–13 Hz range over the left temporal lobe when the field was applied over the hemisphere; instead, the proportion of activity was increased over this region. In addition, application of the fields over the right hemisphere did not significantly change the relative alpha activity over either the left or the right temporal lobes.

Although the experimental results of several researchers have suggested that applied magnetic fields can affect the power spectra of electroencephalographic records (Subrahmanyam et al., 1985; Bell et al., 1992; Persinger et al., 1997) including the specific enhancement of power within the alpha bands over the occipital region (von Klitzing, 1991), the effects from the transcerebral stimulation may not have been direct. Thirty minutes of exposure would have been sufficient to have induced changes in brain chemistry, specifically the release of endogenous opiates, that may have differentially affected the two temporal lobes. It may be of interest that mor-

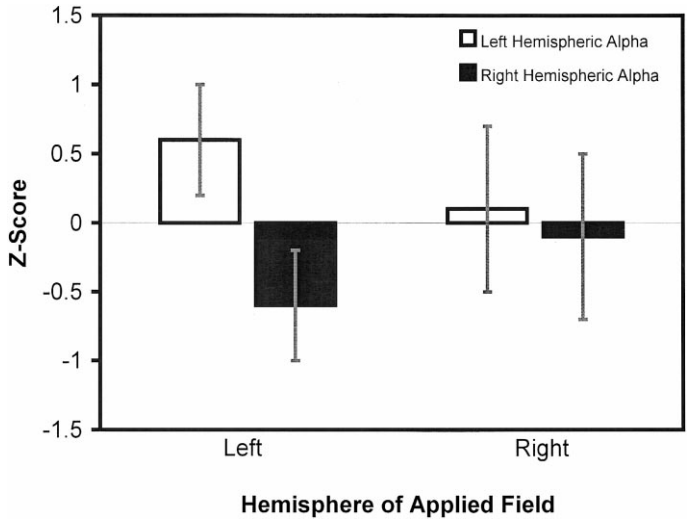

Fig. 2. The *z*-score variations for the proportion of alpha time (referenced to each person's scores) over the left and right temporal lobes as a function of application of weak, complex magnetic fields to the left or right temporoparietal region. Vertical bars indicate S.E. of the mean.

pholine MK 869-induced antagonism of neurokinin (NK 1) receptors, which are concentrated within the amygdala and typically sequester the neuropeptide Substance P (most known for its role in central pain), has been shown to be as effective as traditional antidepressants in populations of depressed patients (Kramer et al., 1998). Transcerebral presentations of the field employed in the present study for 30 min per session once per week for five successful weeks have been associated with marked reductions in depression for patients who sustained recent brain traumas and who did not respond to antidepressant medication. This same complex, magnetic field pattern, when applied to rats for approximately 30 min elevated nociceptive thresholds to foot shock immediately following the exposure and for at least 30 min subsequent to exposure (Fleming et al., 1994).

Although the effect size from the application of the burst-firing magnetic fields was approximately 15% and required the standardization (z-scores) of raw data within each subjects measurements to be discerned, the detection of this effect under conditions of double blind rating and double blind experimentation strongly suggests the phenomenon may be valid. Rodent studies have shown that the effects of weak magnetic fields upon electrical activity within the brain may be modulated by the state of the system. We (Persinger et al., 1991) have hypothesized that when large numbers of neurons within the human cerebral cortices are suddenly deprived of visual and auditory input, they become susceptible transiently to the subtle influence from weak stimuli such as transcerebral magnetic fields. When these transient conditions are not present, even labile, (limbic) epileptic brains require field strengths that are stronger by a factor of approximately 1000 to generate discernable changes in electroencephalographic activity (Fuller et al., 1995).

Acknowledgements

This work was partly supported by a donation from Dr Ted Mann and Professor Dianne Mann. Thanks to Pauline Richards, Catherine Monroe, and Sandra Tiller for technical support.

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